Economic, physical, and political characteristics of neighborhood of residence and the risk of low birth weight.

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Abbreviations: LBW=low birth weight

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ABSTRACT

Low birth weight remains an important public health problem in the U.S. Most research on low birth weight focuses on individual-level determinants of low birth weight such as health behaviors or use of prenatal care. We sought to determine how characteristics of residential neighborhood influenced low birth weight. We first present a theoretically based framework that describes the mechanisms by which neighborhoods can lead to adverse health outcomes. Our research question centered on whether neighborhood economic, physical and political characteristics directly and indirectly influenced the risk of low birth weight and whether neighborhood factors moderated the relation between individual-level risk factors and low birth weight. We used methods of multi-level statistical modelling to investigate our research question. Direct neighborhood level determinants of low birth weight included high crime (OR=2.49), low wealth (OR=5.50) and low level of political organization (2.54). Interactions and confounding between individual- and neighborhood-level characteristics were observed. When multi-level models accounted for neighborhood levels of wealth, the two-fold gap between African-American and White births was no longer significant. Methods of multi-level modelling facilitated testing of a model emphasizing environmental and social factors in determining poor health outcome. The application of such models also resulted in a better explanatory model for low birth weight.

High rates of low birth weight births remain an important public health problem in the U.S., especially among impoverished communities. Most research on low birth weight, however, focuses on individual-level determinants of low birth weight such as maternal education, health behaviors including smoking during pregnancy, and quantity and quality of clinical care (1). Increasingly, public health researchers are recognizing that models of disease etiology that focus exclusively on individual characteristics (e.g., demographic, biologic or personality factors) are insufficient for explaining the complex set of factors that contribute to poor health (2, 3). For example, health behaviors and health outcomes of individuals are influenced by workplace and residential environments (2, 4-14).

Studies on the influence of neighborhood residence on health outcomes often analyze individual- and community-level characteristics separately (15, 16). This has, in part, been due to (1) a lack of available data on the contexts of study subjects, (2) lack of easily accessible statistical methods and software for the analyses of complex multi-level data (17-20), and (3) lack of appropriate theory that explicitly acknowledges the mechanisms by which contexts are related to health outcomes (17, 19, 22-24).

We undertook the current study to contribute to theoretical development of neighborhood effects on health. In particular, we sought to build a conceptual framework describing the mechanisms by which residential characteristics influence health outcomes and low birth weight. We also were interested in answering two research questions concerning the relation between residential neighborhood risk of low birth weight.

(1) Do neighborhood economic, physical and political characteristics directly and indirectly influence the risk of low birth weight?

(2) Do neighborhood economic, physical and political characteristics moderate the relation between individual-level risk factors and low birth weight (LBW)?

Theoretical considerations and conceptual framework.

Neighborhoods have physical, social, economic, and political features that may influence health behaviors and outcomes. To understand how neighborhood of residence might affect adverse pregnancy outcomes such as low birth weight we must begin to understand the mechanisms by which context can potentially influences individual behaviors and outcomes. We present in Figure 1 a conceptual framework for the study of residential neighborhood influence on low birth weight. This framework has three levels of influence--individual, neighborhood, and national/international. All three levels are appropriate targets for public health research, interventions and policy formulation.

The first level of influence is the individual. There have been numerous studies looking at the relation between demographic characteristics (e.g., adolescent pregnancy), social class, medical or biological characteristics (e.g., presence of medical complications such as diabetes), health behaviors (e.g., smoking, alcohol consumption, drug use, and prenatal care utilization) and low birth weight (1, 25, 26). Most studies of low birth weight stay within this level of analysis. So for example, risk factors shown to increase the risk of low birth weight include initiating prenatal care late in pregnancy (27), maternal smoking or exposure to passive smoking (26, 28), low-income (29), and presence of medical complications during pregnancy (30).

The second level of influence is the neighborhood level. Our conceptual framework suggests that several features of residential neighborhood potentially affect the risk of low birth weight. Broadly, these features can be grouped into the physical environment (e.g., presence and quality of parks or conditions of structures and housing), social norms and culture (e.g., belief systems or cultural norms such as preferences regarding infant size or beliefs regarding how to have a healthy pregnancy), and the political and economic structure (e.g., whether communities are organized, voting participation, or presence of businesses). Neighborhood characteristics such as housing type, age, and quality might have direct effects on LBW (e.g., via lead exposures) or might be indirect via their influence on individual level risk for LBW (e.g., women may be less likely to seek care if services such as public transportation are limited in their neighborhoods). In our study, we have information on the physical, political and economic structure of the residential neighborhoods of our study participants (see double lined boxes in Figure 1).

There are several theoretical perspectives that are relevant to gain an understanding of *how* neighborhood factors confer or protect from the risk of LBW (31-33). Deprivation, both economic and social, is one such theory (34-38). Individuals who are socially or economically deprived lack access to necessary goods and services. There are several ways of measuring deprivation and in our study we focus mainly on indicators of economic deprivation (see Table 1).

Table 1. Mechanisms by which neighborhood factors are lead to or protect from LBW.

Mechanisms	Study variables
Economic and Social Deprivation	Housing violations Vehicles per household Average neighborhood wealth Unemployment rate Household crowding Per capita crime rate No. of neighborhood organizations
Urban Press	Housing violations Vacant housing Household crowding Rates of aggravated crime Per capita crime rate
Political Organization	No. of neighborhood organizations

Theories of stress are also relevant for understanding how neighborhood features affect LBW (39). Stress is the generalized response of an organism to noxious or threatening conditions, more generally referred to as stressors (40). Research in the area of environmental stress indicates that stressors are created by and differentially distributed within and between neighborhoods in urban settings. For example, "urban press" is one characteristic of the urban physical and social environment that is relevant for the study of stress caused by neighborhood settings. Urban press is defined as a "flow of stimuli related to the physical, social, visual, and aural aspects of environments" and serves as a source of stressors (Table 1) (41-42). For example, research has shown that residents of neighborhoods with equal residential density, differing only by the presence of small stores, had different levels of stress (43). Residents of city blocks with small stores had higher levels of stress compared to those neighborhoods without stores. Commercial establishments bring with them an increase in visual stimuli, noise, vehicular and pedestrian traffic, and commercially related and non-related social interactions all of which contribute to an increase in stress levels among surrounding residents (43).

Finally, theories from community psychology are relevant for our framework. Community psychologists have explored the ability of communities to identify and formulate solutions for their most pressing problems (44, 45). We hypothesize that neighborhoods that are politically active and organized, for example, through community groups or having high levels of voting participation, are better able to solve community problems compared to neighborhoods that are less active and organized.

Finally, the attributes of neighborhoods that are presented in our framework at level 2 are not inherent traits of communities. Rather, characteristics of neighborhoods are shaped by larger national and global social, economic, political, and demographic trends and influences

(46-48). Demographers and urban sociologists, for example, note that neighborhoods with high rates of unemployment or vacant housing are often the consequence of social processes including: suburbanization of middle- and upper- income residents; deconcentration of manufacturing, retail and wholesale establishments; corresponding declines in blue-collar and low-skill jobs in central cities; corresponding rise in movement of industry to other countries; and less government spending on supporting social programs (e.g., housing) for economically deprived residents (46, 47, 48).

It is important to note, especially when studying health issues related to women, that these larger social processes and trends may have had a greater effect on women than on men. Since women are more likely than men to shoulder child rearing and other household responsibilities in the home, they require jobs that are closer to their places of residence (49). Thus, loss of jobs in central cities has a larger effect on women who are less able to follow businesses that locate in the outer perimeters of cities (49).

The present study focuses on two levels of influence presented in our conceptual framework, the neighborhood and the individual.

METHODS

The analysis presented here is part of a larger study looking at indicators of neighborhood and social risk for poor pregnancy outcome. As part of this study, we collected qualitative (i.e., focus group data) and quantitative data (e.g., community surveys and tapped into routinely available information such as census data) on 29 neighborhoods in Baltimore City that varied by average social class and racial composition. We were interested in exploring the relation of social class and selected neighborhood characteristics to the risk of adverse pregnancy outcomes and health behaviors. Maternal and child health studies often look at outcomes by race or ethnicity. Often the assumptions or theories behind the use of the variables "race" or "ethnicity", and any reported differences, are not explicated. Numerous studies document a gap in the rates of adverse pregnancy outcomes (i.e., low birth weight, infant mortality) for African Americans compared to Whites and that the gap may be increasing (29, 50-53). Yet the reasons for race/ethnic differences, or the factors that race/ethnicity may be serving as a proxy for, are not often stated nor studied. We, too, are examining the relation of self-reported race/ethnicity on low birth weight and are interested in how characteristics of the neighborhood of residence may either help explain the "gap" in low birth weight or how community factors may modify the relation between race/ethnicity to low birth weight. We note, however, that our interpretation and use of race/ethnicity is as a socially determined characteristic of the women in our study and not a biological one (54). That is, any differences in adverse outcomes by race/ethnicity are likely due to differences in social factors (e.g., levels of wealth, poor housing) for each group.

Source of individual-level data.

Data on individual-level information including low birth weight came from computerized birth certificates for the years 1992-1994 for 29 neighborhoods in Baltimore City. These neighborhoods were chosen to represent a range of social class and racial composition. Birth weight is reported on the birth certificate as either grams or pounds and ounces. All birth weights were converted to ounces and low birth weight was defined as an infant weighing less than 5 pounds 8 ounces. Information on demographic, medical, and behavioral characteristics of the mother were also obtained from the birth certificate. Information on health behaviors such as smoking during pregnancy had was severely underreported (e.g., a prevalence of 10% among those who reported that information) and had to be of use in the current study. To be eligible for this study women had to have reported a residence in the address field and no missing data for any of the independent variables at the individual level: age, level of education, race/ethnicity, medical complications affecting pregnancy, type of health insurance, trimester of initiation of prenatal care and marital status. Of the independent variables that we used, medical complications had the greatest number of missing values (9%). However, there were no significant differences between the educational levels, age, and race category for women with and without missing information on medical complications. Three-thousand fifty-nine women were eligible for this study. Birth certificate data in Maryland contain information on the census tract of residence of the mother. This information was used to link the neighborhood characteristic data to the individual-level data (55).

Sources of neighborhood-level data.

Data for the economic, physical, and political features of neighborhoods were obtained from three sources of routinely available data. Community characteristics may be measured as aggregated individual-level data (e.g., proportion of female headed households) or as non-aggregated variables (e.g., numbers of parks, crime rate, businesses, community groups, housing characteristics) (56). Information on crime and housing characteristics (violations and vacancies), and number of community organizations came from data collected by the City Planning office of the Baltimore City local government. Unemployment rates were obtained from the Maryland Department of Economic and Employment Development office. All other data on neighborhood characteristics came from Claritas, a commercial source of 1990 census and other marketing information.

Definitions of individual-level independent variables.

Independent variables were either continuous or dichotomous. Maternal age and maternal education were a continuous variables. The variables unmarried, medical complications, late prenatal care initiation, sex of infant, African-American race, and medical assistance were coded as "1" for yes and 0 for no. A "1" for unmarried indicated all women who were not legally married. Late prenatal care initiation was coded as "1" if the data on the birth certificate indicated that the mother sought prenatal care later than the 2nd trimester of pregnancy or had no prenatal care. For sex of infant, male sex was represented by a "1". If the birth certificate indicated that a woman experienced any medical complications during pregnancy (e.g., diabetes, hypertension, anemia) this variable was coded as a "1". Birth certificates that indicated that the mother was of African-American race/ethnicity were coded as "1" on the race/ethnicity variable. Those women whose birth certificate indicated the source of insurance was medical assistance were coded as "1" on that variable.

Definitions of neighborhood-level variables.

Physical conditions. Rates of housing violations and vacancies were created by calculating the proportion of all housing in a specific census tract that had reported violations and all housing that were vacant. For violations, a dichotomous variable was created where all census tracts with greater than 10% housing violations were coded as a "1" on the housing violation variable.

Economic conditions. Unemployment rates, proportion of households that are crowded, and rates of aggravated assaults were continuous variables in our analysis. Household crowding was the proportion of homes that had greater than 4 persons, a proxy for households with more than 1 person per room. Per capita rates of aggravated assault were created by calculating the numbers of aggravated assaults divided by the total numbers of persons for each of the 29 census tracts. Average wealth which includes information on ownership and assets (e.g., equity in homes, vehicles, assets, mortgages and other debts and real estate ownership) was obtained from Claritas. Wealth is a better assessment than annual income of economic resources that are available to families. Moreover, recent national survey data show that differences in median wealth of black and white families may be far greater than median income differences (57). Specifically, the Black/White (B/W) ratio of median family income was 1.6 ($25,000 to $15,630) while the B/W ratio of median wealth of those same families was 11.8 ($43,800 to $3,700) (57). Thus, wealth may more accurately capture social class *differences* between African Americans and Whites than other indicators such as income and education. We dichotomized average wealth of census tracts into a zero-one variable with census tracts having a wealth greater than $89,000 being coded as "1". We also created a four category variable representing historical poverty for our study neighborhoods. We identified census tracts which have been "traditionally poor" (>35% households continuously in poverty since before 1970), "emerging poor" (>35% households continuously in poverty since 1970) and "newly poor" (>35% poverty since 1980). The >35% criteria similar to that used by previous authors (58, 59). Overall per capita crime was dichotomized where census tracts with crime rates $10% were coded as "1" and all others coded as zero. Automotive vehicles per household was also dichotomized with census tracts having an average $0.50 vehicles per household being coded as a 1 and all others being coded as zero.

Political characteristics. The number of community organizations was considered a continuous variable.

Statistical methods We first generated descriptive statistics on the individuals in our study and on the neighborhoods. We then conducted our multivariate analysis in two stages.

We first obtained a logistic regression model for the only the individual-level variables. We performed this logistic regression analysis in SPSS -PC for Windows. Once a "best-fit" individual-level logistic regression model was obtained we began to assess the importance of the neighborhood- level factors by performing two-level logistic regression analysis in the statistical software package Mln (60). This software package allows for the analysis of any number of levels of data. MLn, or a similar package that accommodates multiple levels of data, had to be used to account for the two sources of random components of the model (see equations below). For example, if we are building a simple 2-level model with the independent variables maternal age, maternal education, and average neighborhood wealth the level-1 and level-2 models would be written as:

(level-1) logit $LBW_i = \$_o + \$_1$ Maternal age + $\$_2$Maternal Education + r_i

(level-2 intercept) $[\$_0] = O_{00} + O_{01}$Wealth + u_{oj}

(level-2 age) $[\$_1] = O_{10} + O_{11}$Wealth + u_{1j}

(level-2 education) $[\$_2] = O_{20} + O_{21}$Wealth + u_{2j}

Mln actually estimates all the ß's and the O's simultaneously. The separate models above would be fit in MLn as the following:

logit $LBW_{ij} = O_{00} + O_{01}$Wealth + O_{10}(Age) + O_{11}Wealth(Age) + O_{20}(Education) + O_{21}Wealth(Education) +$r_{ij} + u_{0j} + u_{1j} + u_{2j}$

In the equations above, r_{ij}, u_{0j}, u_{1j}, and u_{2j} are the random components of the model. Use of MLn, or a method that allows for the multiple random components, is necessary for multi-level models. Using MLn we were able to assess not only the direct effects of the neighborhood-level factors but also the moderating effects of the neighborhood factors on the individual-level variables. O_{01}Wealth in the equations above represents the direct effect of wealth on low birth weight. O_{21}Wealth(Education) above represents the moderating effect of wealth on the relation between maternal education and low birth weight. For example, we could determine whether the protective effect of increased maternal education was similar in wealthy and non-wealthy neighborhoods or whether the protective effect was more prominent in neighborhoods with different levels of wealth. Our model building approach allowed us to determine whether there was any confounding operating between the two levels of data. We looked for any substantial changes in the beta and standard error estimates of the level-1 variables with and without the level-2 factors in the model to cross-level identify confounding.

RESULTS

Descriptive statistics.

The characteristics of the 3059 women and the 29 study neighborhoods are presented in Table 2. The overall low birth weight rate of 13.9% is slightly higher than the overall low birth weight rate for Baltimore of 12%. Similarly, a higher proportion of women initiated prenatal care late (19.2%) and were on or were pending medical assistance health insurance (79.2%) compared to Baltimore City as a whole (45%).

Thirty-four percent of the neighborhoods have been traditionally poor and just over half (51.8%) never had >35% of households below poverty level. The average number of community groups per neighborhood was 4 with a range of 1-12 (Table 2).

Table 3 shows the variation of selected individual-level characteristics across the neighborhoods. The neighborhoods are ordered by low, medium and high risk. For some characteristics (e.g., marital status and proportion of women with medical assistance health insurance) there is a wide variation across the neighborhoods within the same level of risk. For example, the LBW rate varies from as low as 3.2% to as high as 30.4% within the medium to high risk neighborhoods (Table 3).

Level-1 logistic regression.

The "best-fit" logistic regression model for individual characteristics is presented in Table 4. Women who had medical complications affecting pregnancy had twice the risk of having a low birth weight infant compared to women without complications. Being unmarried or African-American maternal race increased the risk of low birth weight by 1.87 and 1.73, respectively. Having medical assistance insurance was not a significant determinant of low birth weight in our sample.

Multi-level regression.

Model building for multi-level logistic regression followed a systematic method. First, level-1 variables from the best-fit model were entered into the regression. The direct contributions of the neighborhood characteristics were then tested by entering the level-2 variables one at a time. For each model, likelihood ratio tests were performed to assess the importance of each variable and changes in beta estimates and standard errors for the individual-level variables were observed to note any confounding effects. Important confounding effects were observed for race and neighborhood wealth. Once average neighborhood wealth was entered into the models the African-American maternal race was no longer a statistically significant determinant of low birth weight. The next step in the model building process involved the examination of moderating effects of the level-2 variables. Interaction terms for each of the level-1 with each of the level-2 variables were tested one at a time as described above. Variables were retained if they were significantly associated with the outcome at the $p<0.05$ level or if the two-tailed likelihood ratio test was less than $p<0.02$ (60). Three variables met the latter criteria and were considered adjustment variables. The resulting best-fit multi-level model for variables that were significantly associated with the outcome are presented in Table 5. Beta estimates and standard errors for adjustment variables are not presented in Table 5.

There are notable differences for the individual-level beta estimates and standard errors for level-1 only and multi-level logistic models. Maternal race is no longer a significant predictor of low birth weight once the model is adjusted for neighborhood characteristics. The protective effect of increasing maternal education changed by 9% from an odds of 0.93 to 0.85. The risk of being unmarried increased two-fold from 1.87 to 4.37. These difference between the individual-level only and the multi-level model indicate that there is confounding between the level-1 and level-2 variables.

There were moderating effects of level-2 variables for four of the individual-level factors. Average neighborhood wealth moderated the effect of marital status on the risk of low birth weight (see Figure 2A). We used married wealthy women for our reference group (OR=1.0). Being unmarried and in a low wealth neighborhood increased the odds four-fold compared to our reference group. Being married in low-wealth neighborhoods yielded a similar risk of low birth weight as for those women living in wealthy neighborhoods. This relation was not due to a lack of young unmarried mothers in wealthier neighborhoods as rates of births to unmarried mothers under 18 was lower but comparable to rates seen in non-wealthy neighborhoods.

The number of community groups was a moderator for the relation between maternal education and low birth weight (see Figure 2B). In general, women giving birth in very organized neighborhoods (with 9 community groups) compared to 'average' organized neighborhoods (with 4 community groups) had lower risks of having an low birth weight infant. Also, women with fewer years of schooling (10 years) compared to more years of schooling (13 years) had a higher risk of low birth weight. However, the difference in low birth weight risk for women with low and high levels of education differed by level of neighborhood organization. The reduction in LBW risk for having 13 years of schooling vs. having 10 years of schooling was quite a bit more pronounced in an 'average' organized neighborhood compared to very organized neighborhoods (Figure 2B).

DISCUSSION

We began the paper by proposing a theoretically driven conceptual framework describing the relation between residential neighborhood characteristics and adverse pregnancy outcome. We were able to use methods of multi-level modeling to test the relations in this model. Our findings indicate that neighborhood economic and political characteristics directly influence the risk of low birth weight. Not surprisingly high crime and low wealth neighborhoods increase the risk of low birth weight. The more organized the neighborhood, the lower the risk of low birth weight. Previous studies have shown that "political empowerment" at the level of cities is related to improved health and pregnancy outcomes (15). Our study takes that notion to a more local level and shows that political organization or "empowerment" at the neighborhood level may protect for adverse health.

We found that neighborhood economic and political characteristics moderated the relation between individual-level risk factors and low birth weight which suggests that individual-level risk factors for low birth weight are influenced by the context in which they occur. This potentially has important policy implications. For example, we found "birth out of wedlock" did not confer the same risk if you lived in wealthy neighborhoods compared to living in non-wealthy neighborhoods. Thus, the risk of low birth weight associated with being unmarried may have important economic and social determinants that would not be noted if only individual level data are used.

We also observed some confounding between level-1 and level-2 variables that occurs when we do not have neighborhood level variables in the model. Thus, not only do neighborhood level variables moderate individual-level risks for low birth weight but they also act as confounders.

Limitations of our study include the following. First, we could not use records for all births in our study neighborhoods because some birth certificates had missing data on key study variables. We did, however, look at the demographic profiles of women who did and did not have missing data and found no significant differences. Moreover, the large size of our original sample allowed us to accommodate the attrition due to missing data while having little impact upon statistical power. We did not have information on length of residence at current address for women in our sample. Such information would be useful, if not necessary, to determine whether women were actually residents of particular neighborhoods throughout the duration of their pregnancies, the "exposure period" for our study. Given that we oversampled low-income women it is likely that some women in our study moved during their pregnancies. However, we anticipate that most movement would have been to and from a neighborhood of similar economic and social characteristics. Future studies of contextual effects using primary data collection might investigate the extent of such movement during pregnancy as well as whether migration occurs to and from neighborhoods of similar characteristics.

A notable finding from our two-level model was that the significant increased risk of LBW for African-American women compared to Whites, which was observed for both the individual-level logistic regression model and initially in our two-level regression model, was no longer significant once neighborhood average wealth was put into the model. Past studies have been unable to account for Black/White gap when "adjusting for" socioeconomic factors. Previous studies, however, have usually used maternal education (51) or, more rarely, family income (29, 52) as the adjustment variable. As noted earlier, income differences may not fully account for the economic differences between African Americans and Whites (57). This is the first study on perinatal outcomes, to our knowledge, to adjust for differences in levels of wealth between African Americans and Whites. Wealth or proxies for wealth should be used in studies in the future as it is a more accurate indicator of the total economic resources available to an individual or family.

Several parts of our theoretical framework were confirmed in our multi-level analysis. Neighborhood economic and political characteristics were important determinants of LBW and suggests that economic and social deprivation and political empowerment or organization may be important mechanisms that influence health. Although indicators of the physical environment were not associated with low birth weight in our study, future studies might collect better indicators of urban press (e.g., noise levels, information on social areas for gathering such as businesses or recreation centers, and levels of pollution) to determine whether they are associated with adverse health. The use of multi-level modelling also facilitated the identification of a better explanatory model for LBW and the detection of moderating and confounding effects of neighborhood level variables with individual-level variables.

Future studies might look at other level-2 contexts (e.g., workplace characteristics) or expand the number of levels and the capture national and internal processes that we specify in our third level of influence (Figure 1). For example, if such models were constructed for a larger geographic area that included several states, regional migration and employment trends could be included as third level variables.

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